Survival and growth of Puget Sound chinook salmon in response to climate-induced competition with pink salmon

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Ultimate Study Questions

- Climate implicated in salmon survival change, but what are mechanisms?

- A number of studies indicate density-dependent growth at sea, but does this lead to reduced survival?

- Is prey availability in Puget Sound sufficient to support chinook salmon without additional mortality at higher densities?

Approach

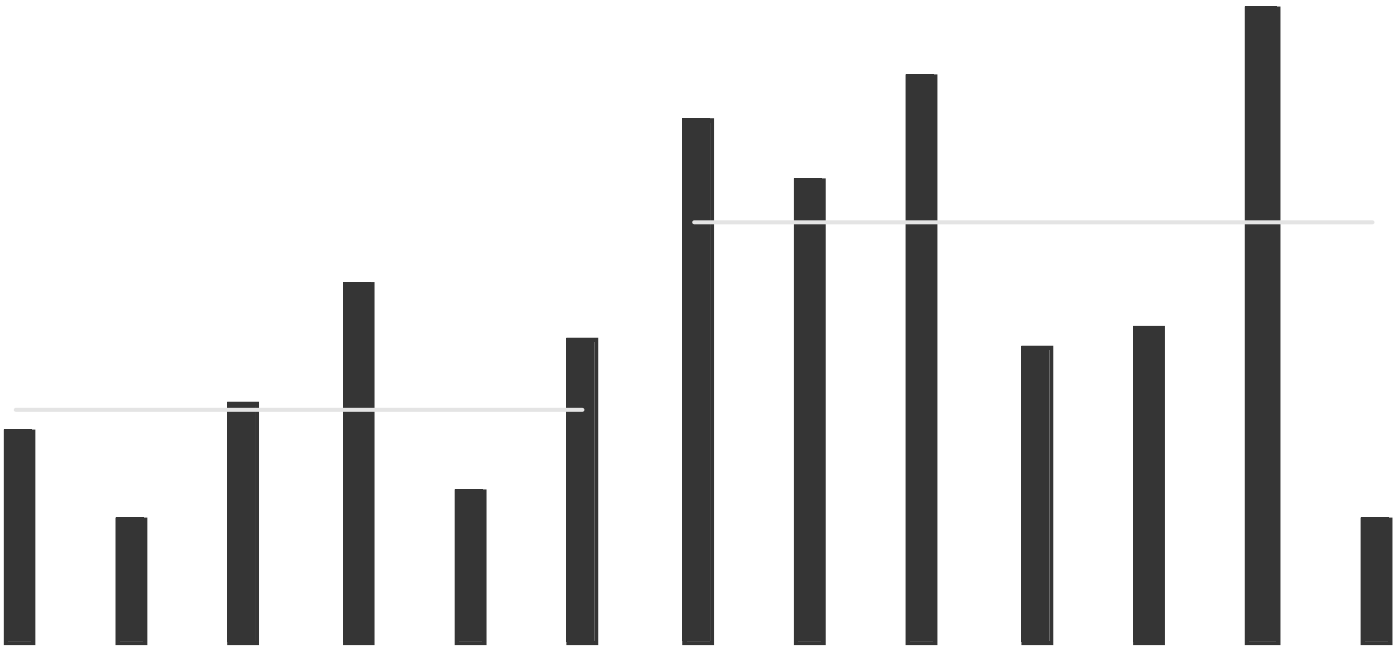
- Utilize unique odd/even pattern of abundance shown by pink salmon - a natural experimental control.

Key Factors

- Pink salmon enter Puget Sound earlier than most subyearling chinook salmon; most leave by July.
- Pink salmon are highly abundant and grow rapidly (eat lots of prey).
- Pink salmon feed on lower trophic level prey.
- Many subyearling chinook enter Puget Sound when invertebrate marine prey are declining and remain until fall.

Puget Sound Adult Pink Salmon

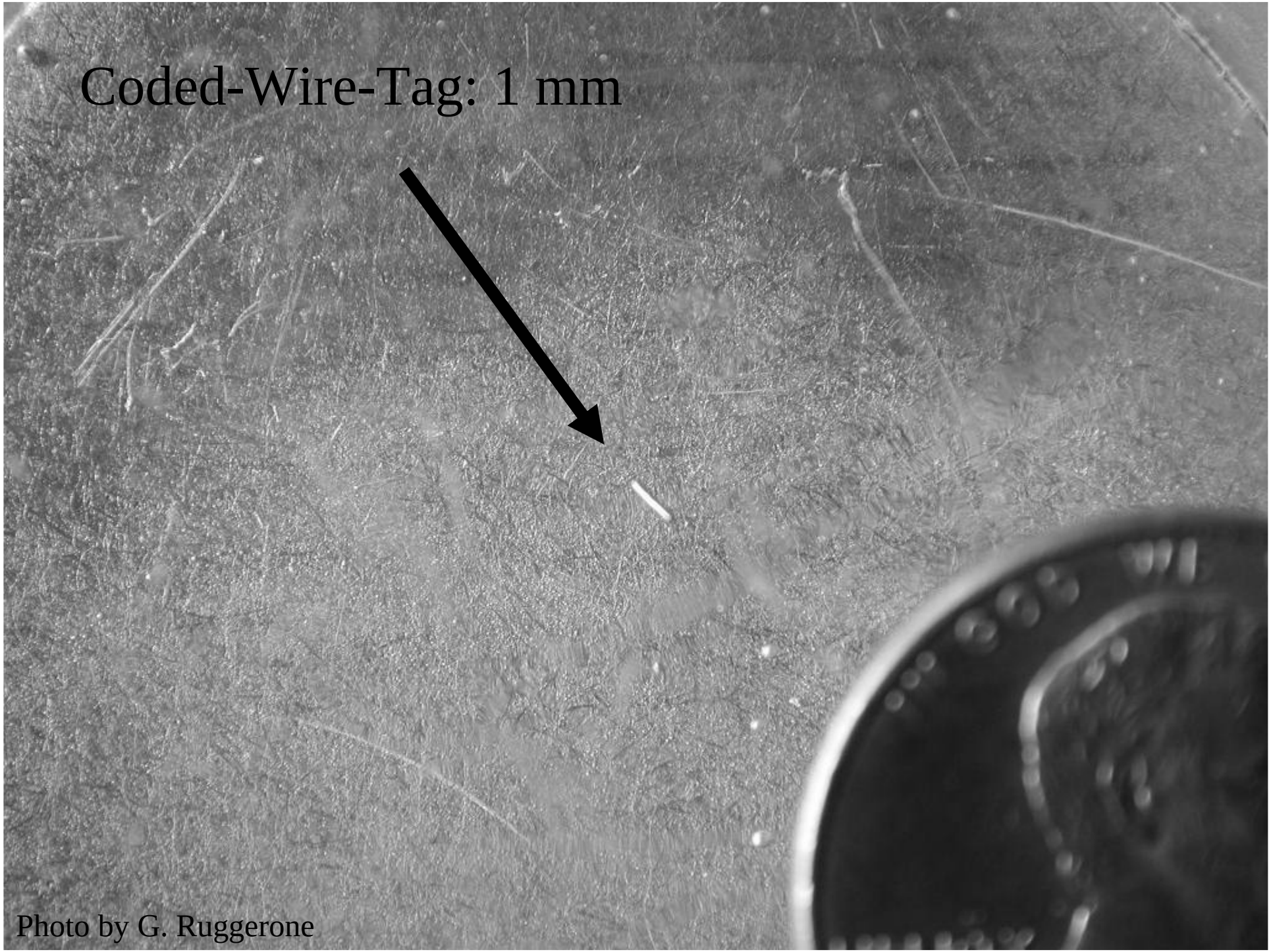
(odd-year adults; even-year smolt)



Puget Sound Chinook Competition with Pink Salmon

- Release to recovery survival rates.
- Size at age.
- Age at maturation.
- Tested hypothesis with coded-wire tag database, release years 1972-1997.

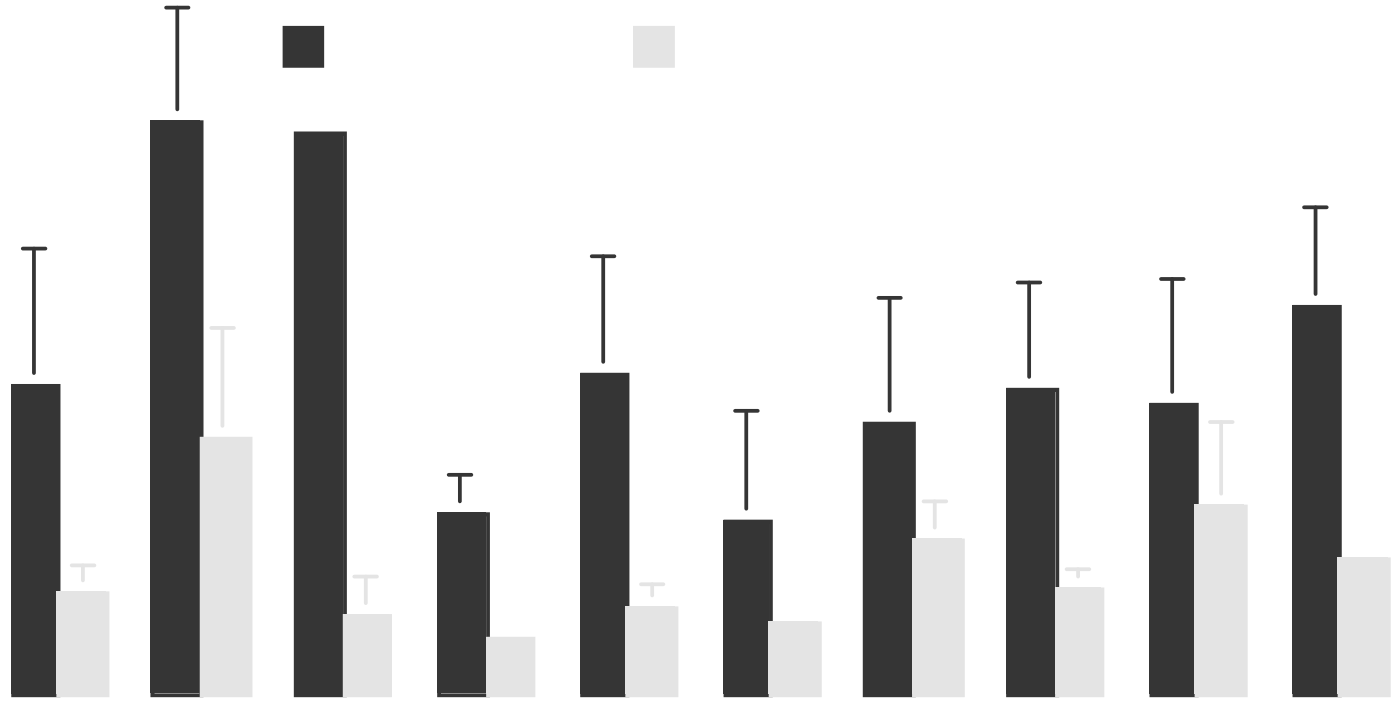
Inserting Coded-Wire-Tag in Salmon

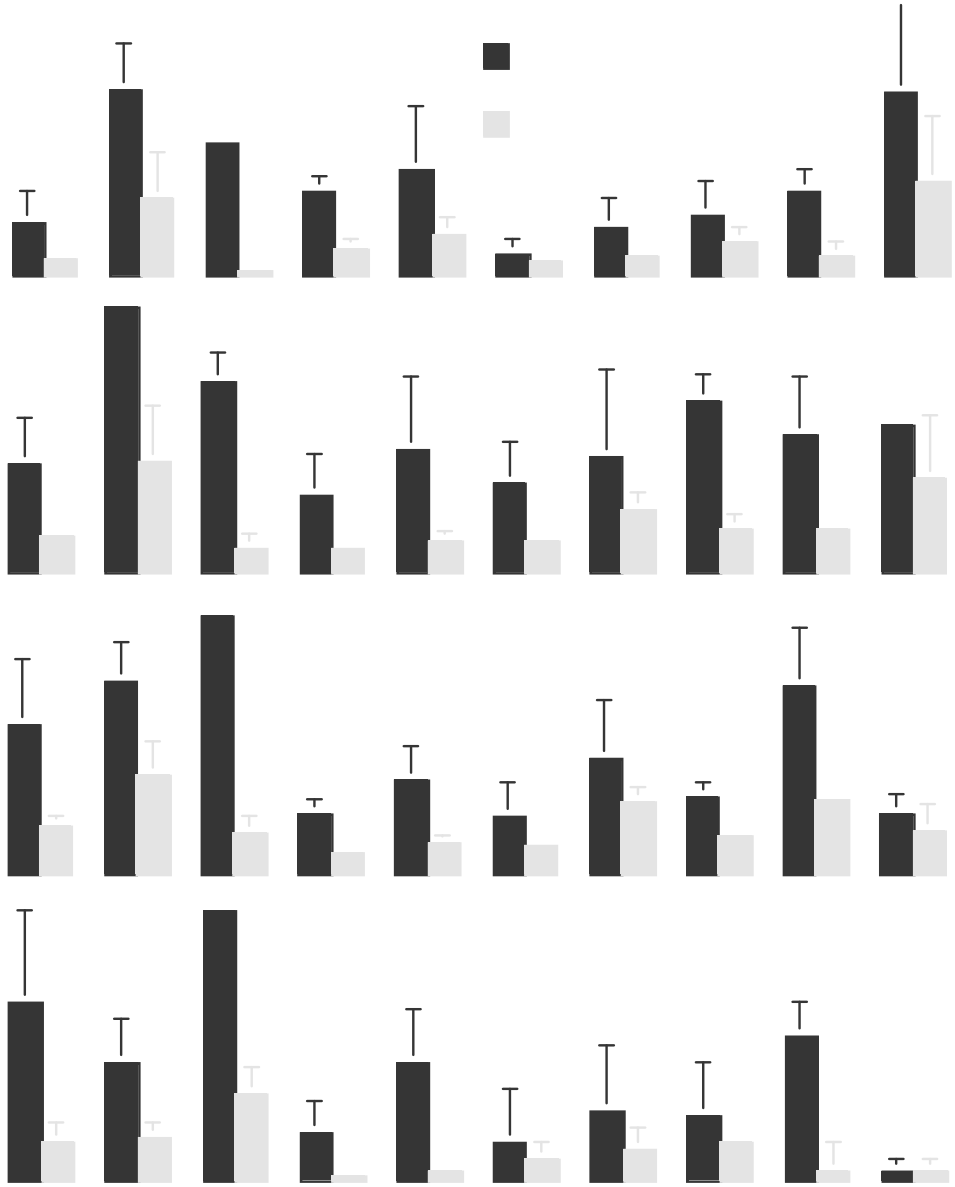

Coded-Wire-Tag: 1 mm
Photo by G. Ruggerone

Release of CWT Chinook salmon, 1984-1997

Stock	No. years	No. CWT fish per year	Avg. weight (g)
Duwamish	12	246,780	5.9
Grover	13	171,134	7.7
Lk Washington	3	196,029	4.8
Minter	10	206,778	8.3
Nisqually	14	209,292	8.5
Nooksack	9	288,285	5.6
Sammish	12	202,742	5.0
Skagit	6	197,942	6.4
Stillaguamish	10	112,653	5.6
Tulalip	5	180,524	5.0
Total 1984-97:		19,016,328	
Total: all study areas:		53,547,480	

Chinook Survival 62% Lower When Migrating in Even Years w/ Pinks, 1984-97



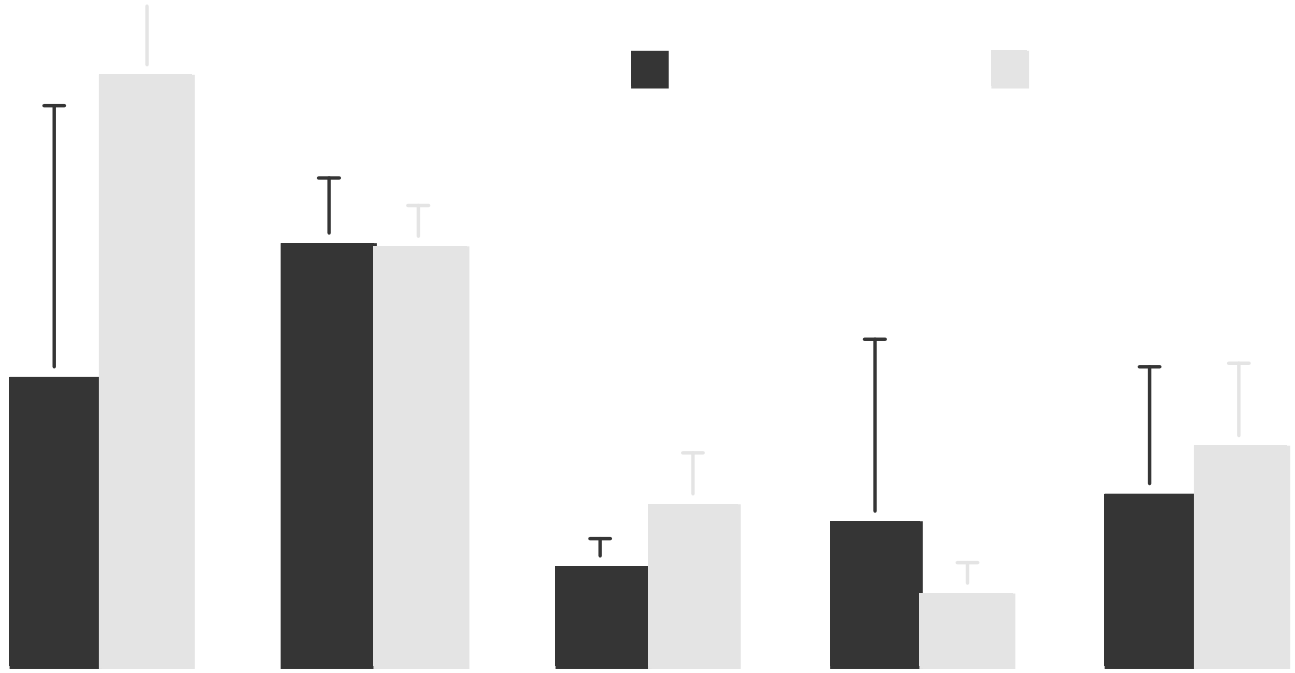


Even-year mortality established during 1st year at sea

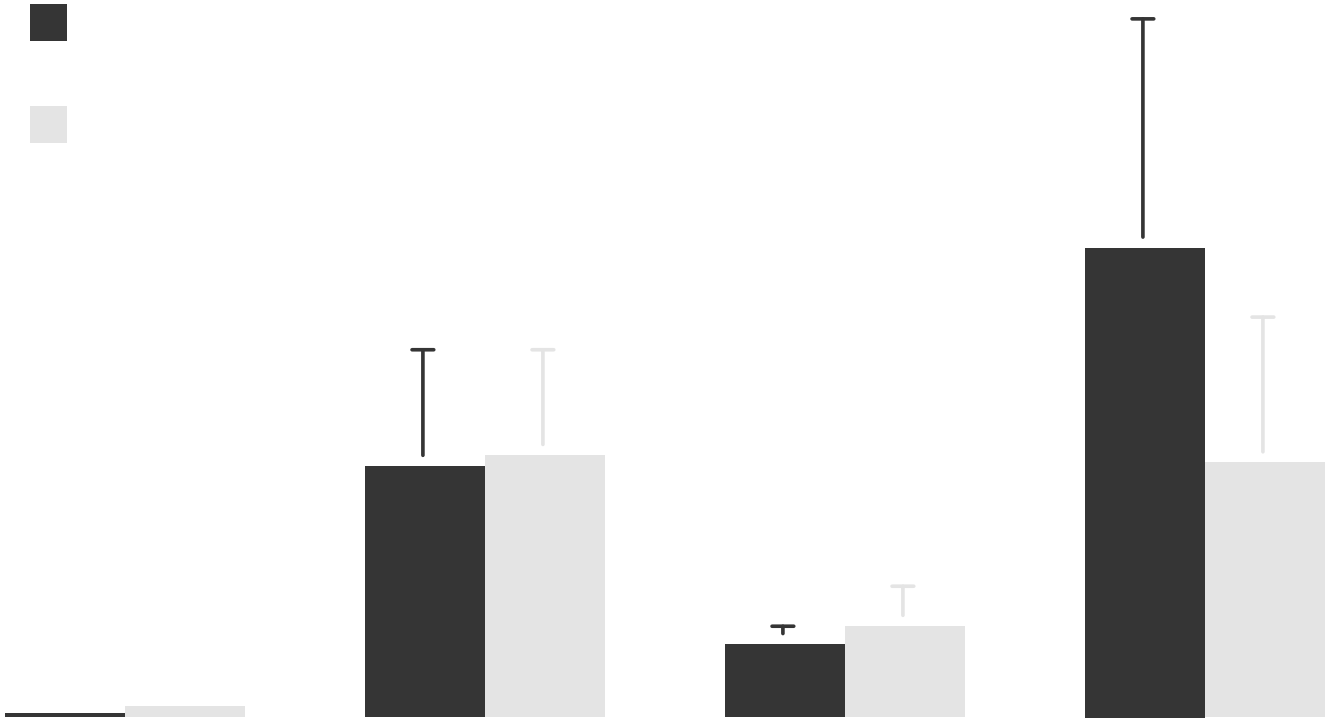
Does this odd-even year survival pattern occur in areas where few pink salmon?

- Washington Coast
- Lower Vancouver Island

Washington Coast Chinook Survival: No Pinks, No Pattern, 1984-97



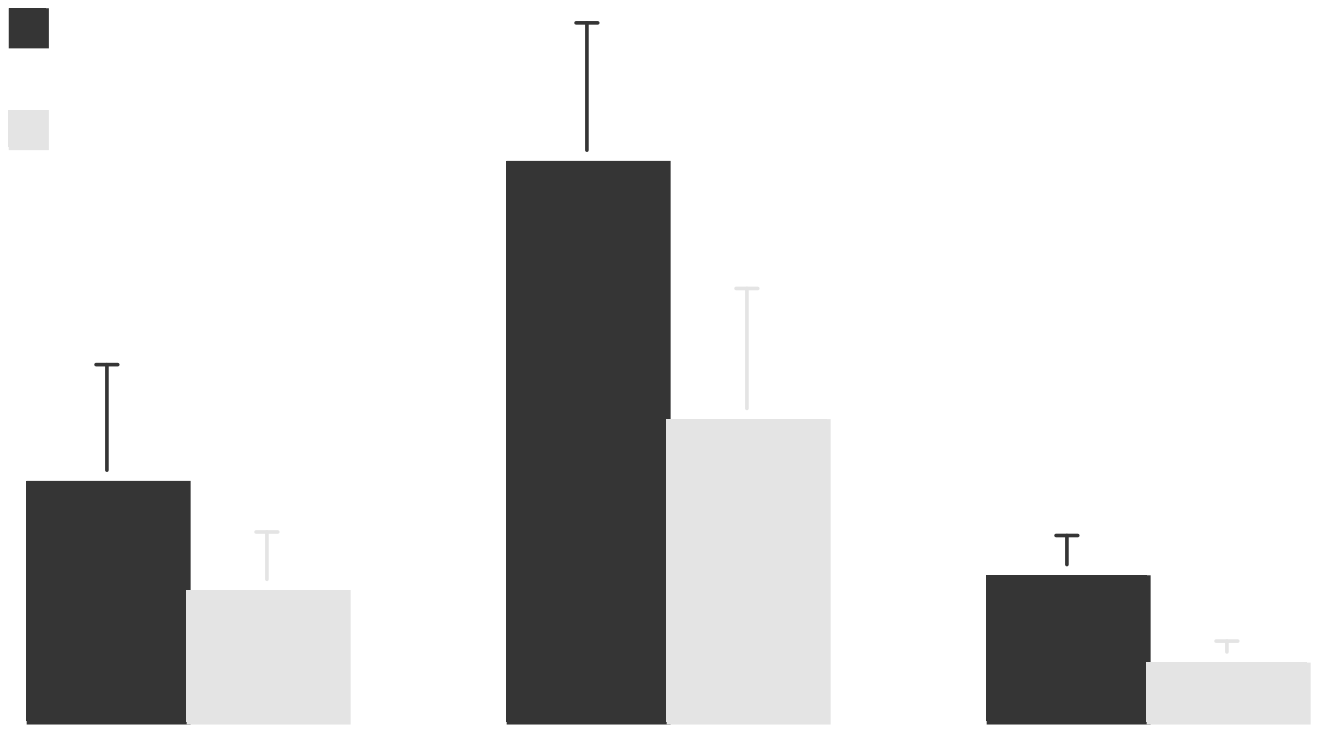
Lower Vancouver Island:
Few Pinks, No Pattern, 1984-97



Fraser R: 15 million pink run in odd years.

Does odd/even year pattern occur among Fraser R. chinook stocks?

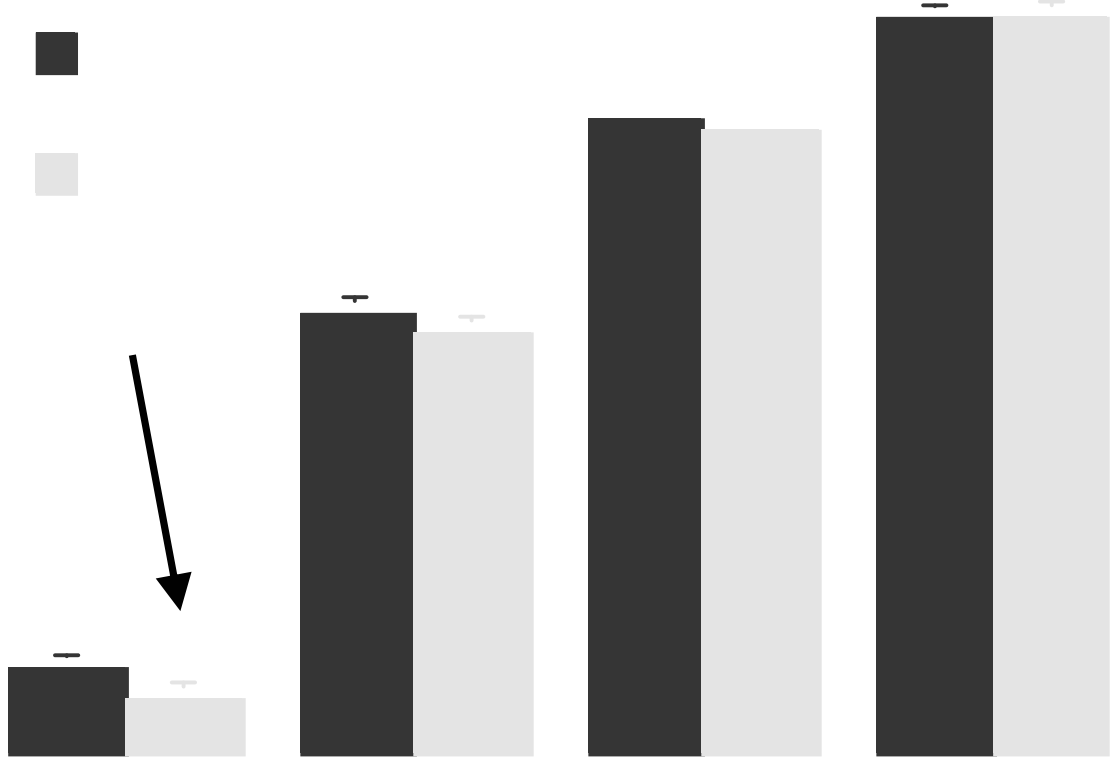
Fraser River Pinks:
Reduced Chinook Survival, 1984-97



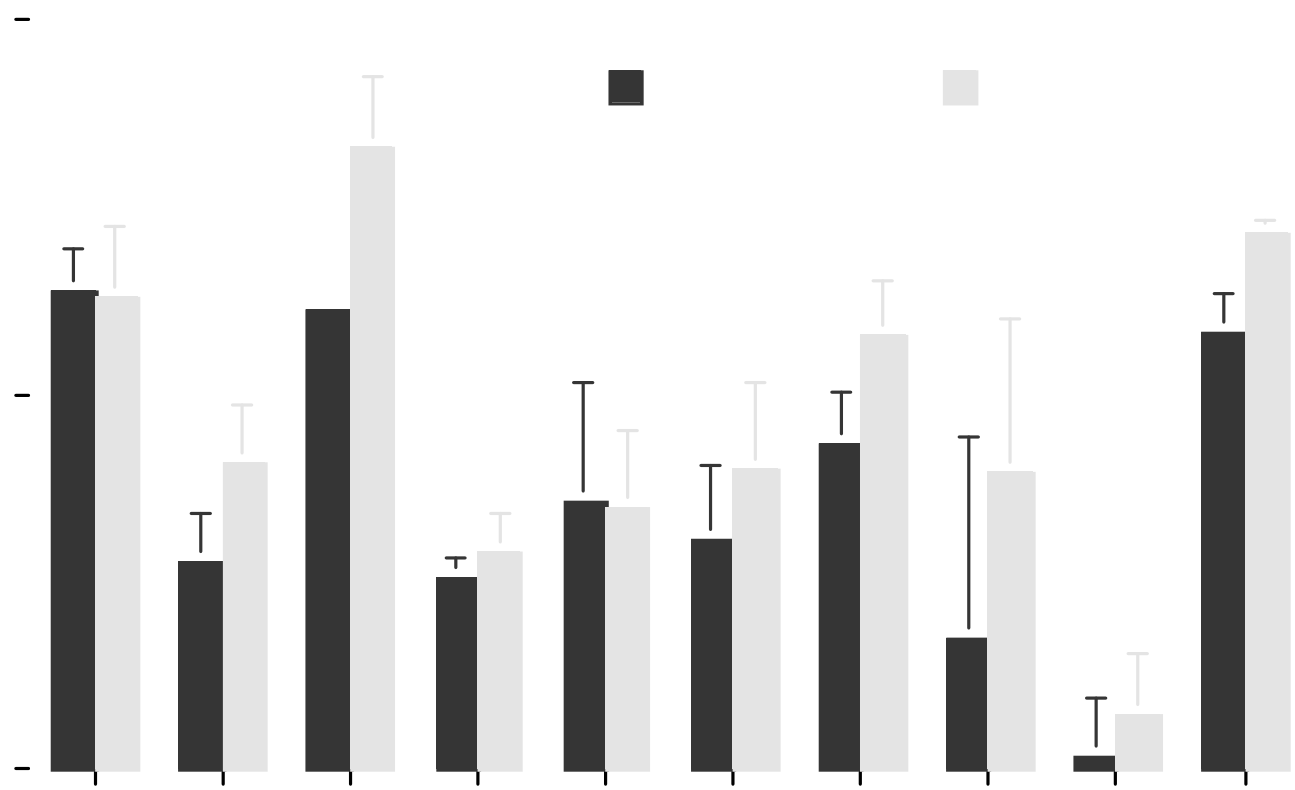
If competition with pink salmon, then might expect to see:

- Reduced growth of chinook salmon
- Delayed maturation of chinook salmon

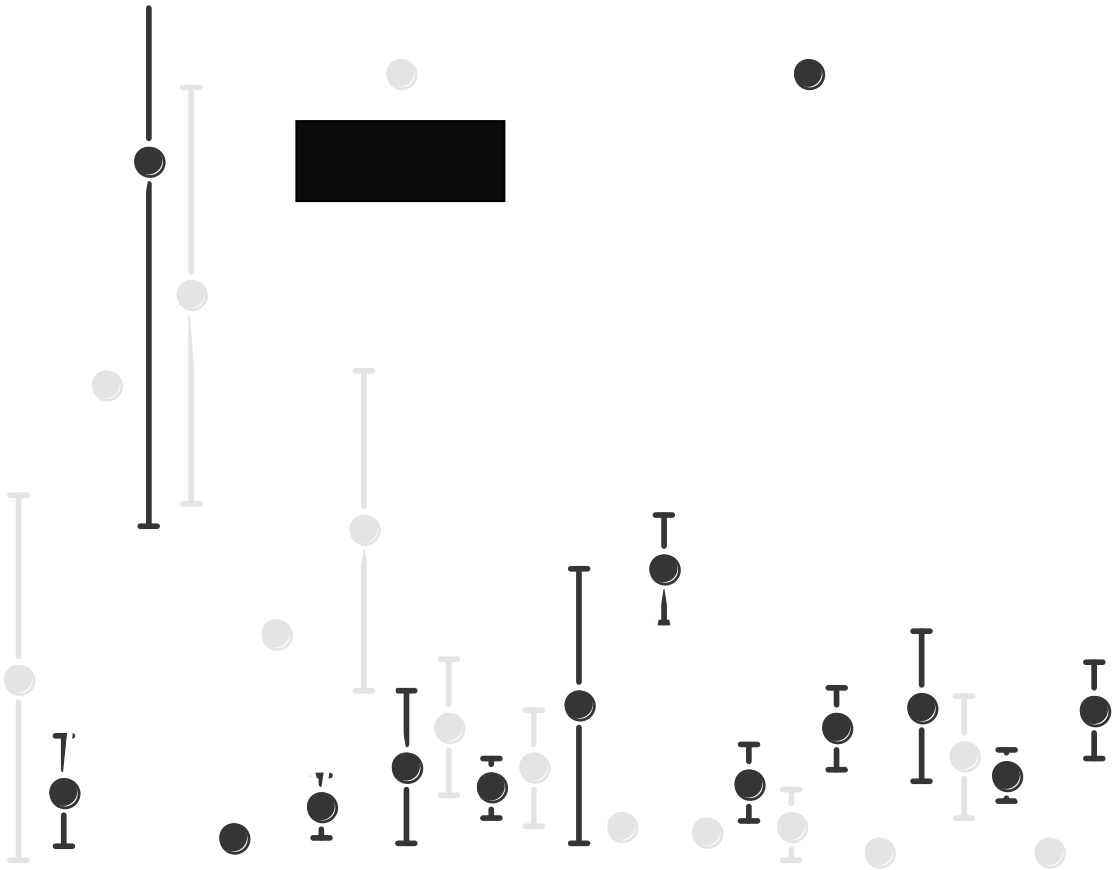
Chinook Growth Reduced 1st year at Sea Even-Year Smolts, 1984-87



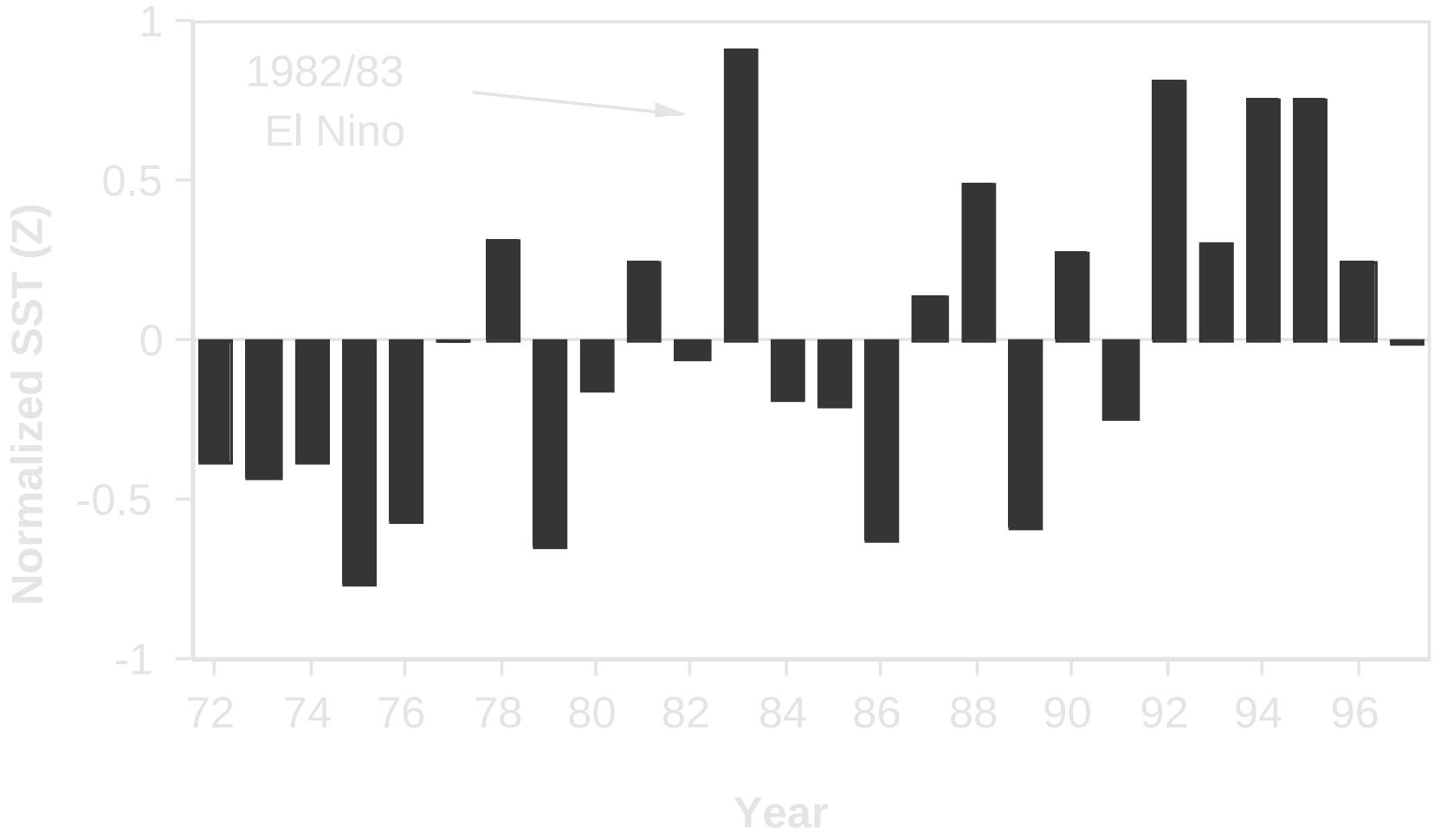
Age at maturation Delayed: Even-Year Smolts, 1984-97



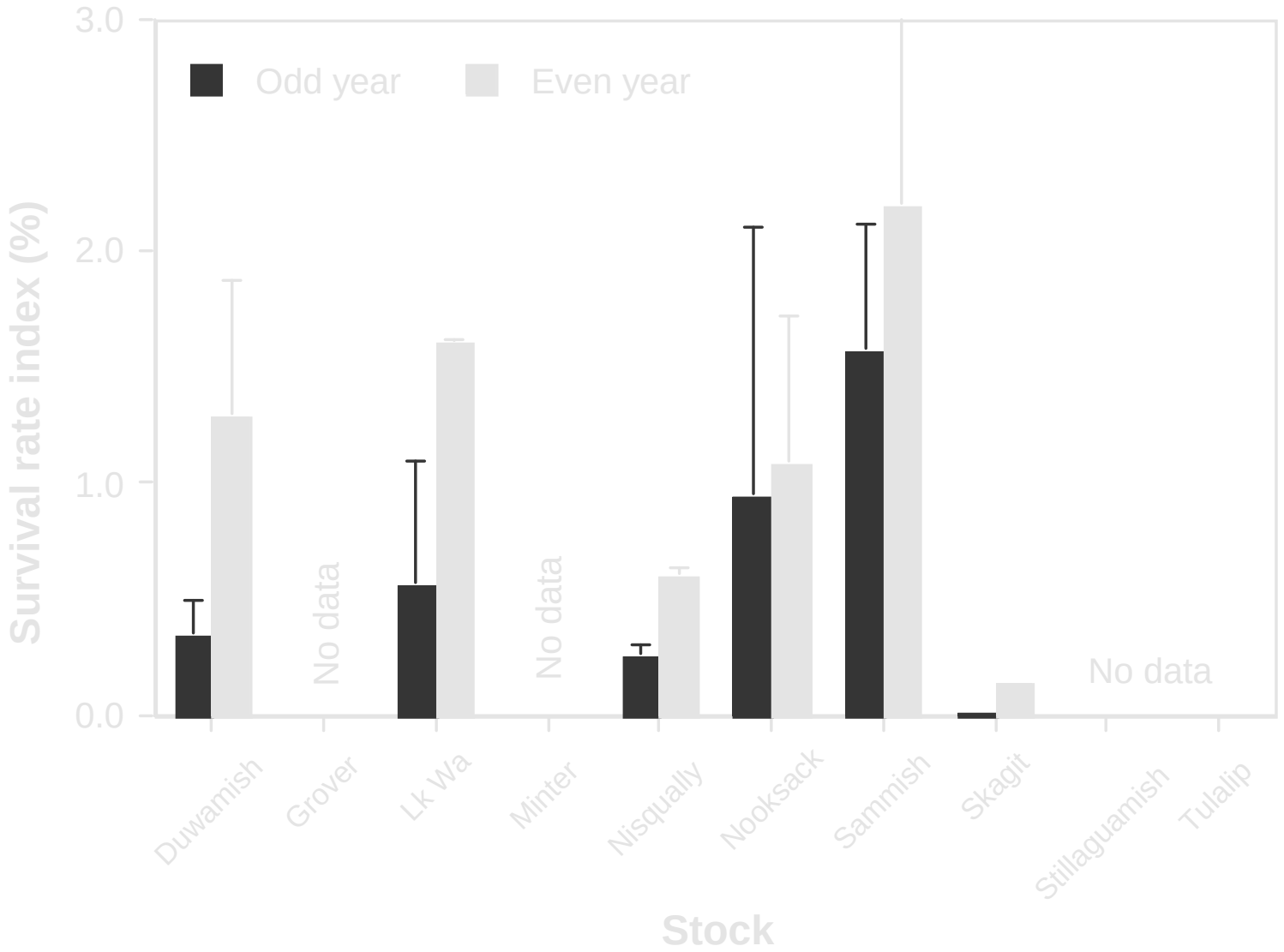
Survival Pattern Shift After 1982/83 El Nino



Sea-surface Temperature, Strait Juan de Fuca



Survival, 1972-1983



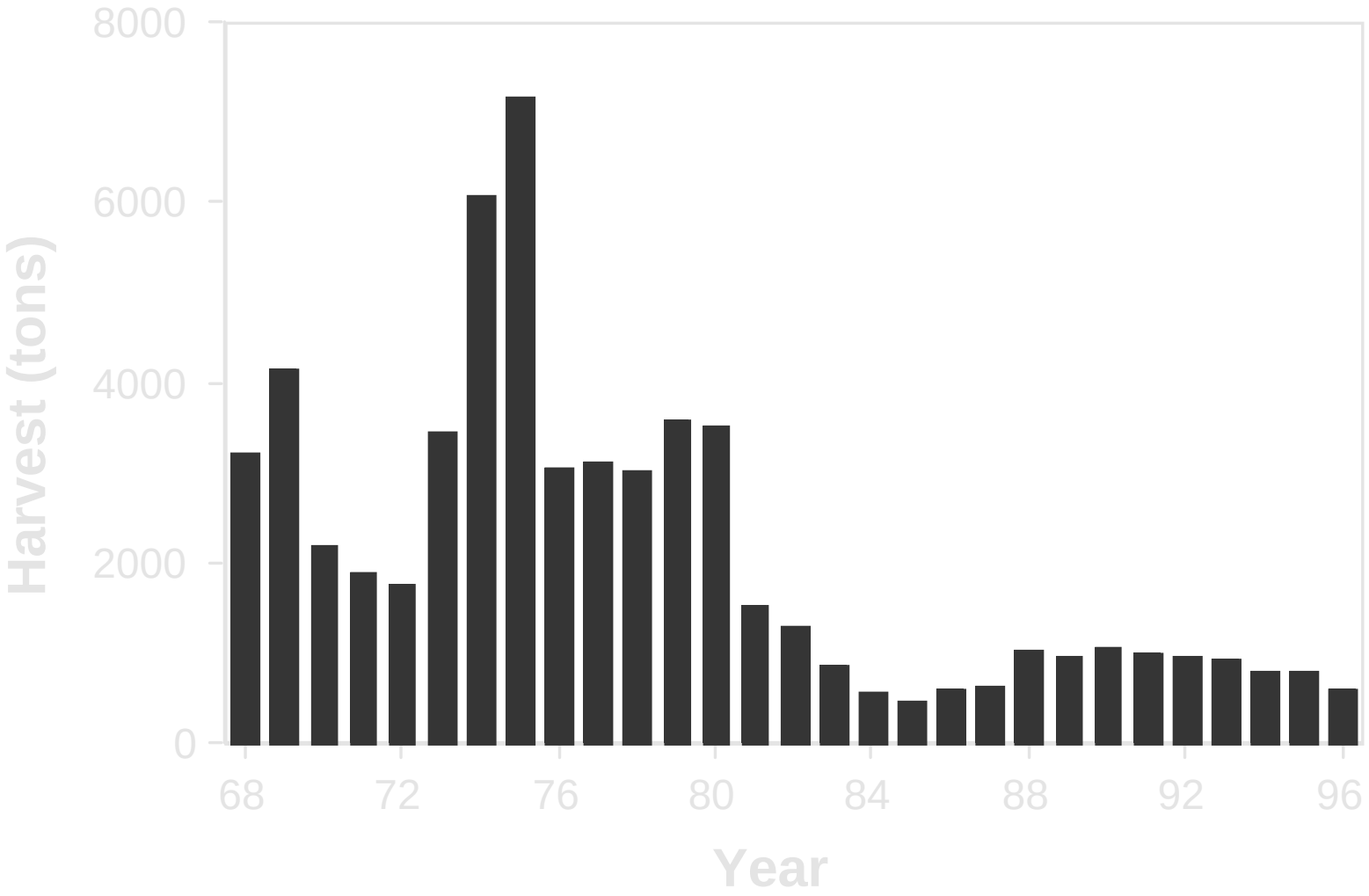
So why did Survival pattern flip-flop?

- Prey abundance declined in recent period.
- Pink salmon abundance increased.
- Predators were much less abundant in recent period.

Zooplankton Timing Shift & Abundance Decline

- Zooplankton peaked 1 month earlier in 1990s vs 1970s (Bornhold 1999) (favors pink salmon, early spawning herring)
- Coho prey reduction late 1980s & 1990s (Beamish studies)
- Chinook enter marine water when marine invertebrate prey abundance and size are declining.

Puget Sound Herring Decline

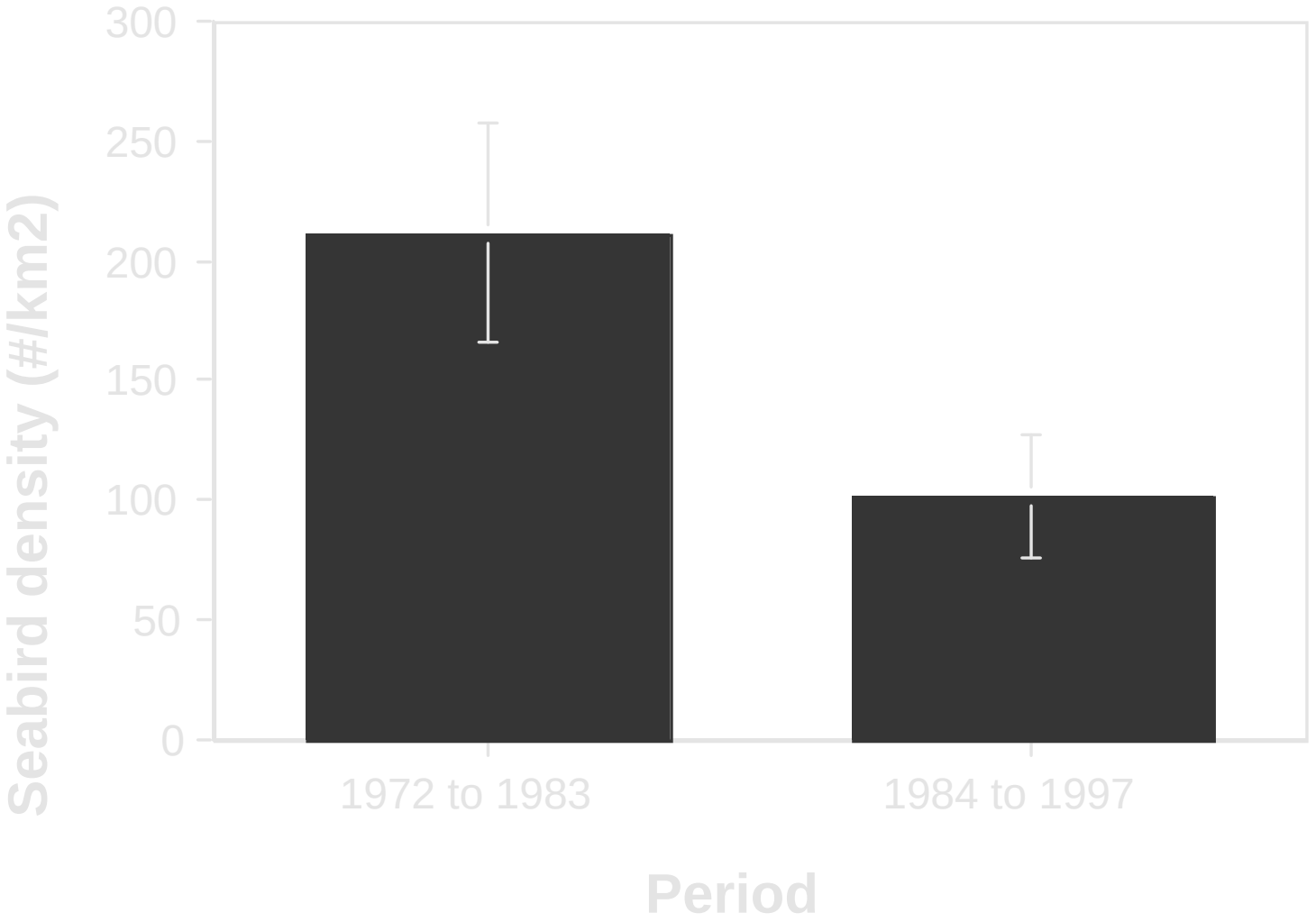


Decline of Predators

- Picivorous seabirds
- Dog fish
- Lamprey (major predator Fraser R. plume)
- Hake

- Harbor seals eat mostly adults (population increase)

Piscivorous Seabird Decline



Data source: PSWQAT 2002

Summary: 1972-1983

- Prey abundance appeared to be more abundant; peak production was later.
- Growth conditions more favorable for chinook salmon, no apparent competition effects.
- Predator abundances relatively high.
- Pink salmon less abundant, but provide buffer to predation.

Summary: 1984-1997

- 1982/83 El Nino & subsequent El Nino.
- Timing of prey production shifted 1 month earlier, apparently leading to reduced prey for chinook.
- Pink salmon benefit from early prey production, abundance nearly doubles.
- Lower prey production & abundant pink salmon led to reduced growth & survival of chinook salmon in even-numbered years.

Study Implications

- Growth is an important determinant of chinook survival.

- Hatcheries: avg. 53 ± 7 million subyearling chinook per year, 1984-1997.

Study Implications

- Habitat: Conditions that favor greater growth in freshwater, estuarine and nearshore areas are especially important during periods of low marine prey production.

- Research is needed to better understand the complex trophic dynamics leading to the odd/even year pattern of chinook growth and survival.

Copyright acknowledgement: The CJFAS requested that we note that the figures shown in this presentation are modified from a related manuscript currently under revision at the Canadian Journal Fisheries and Aquatic Sciences (CJFAS).